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(54) A plurality of fuel cells stacked in modular configuration and fuel cell stack arrays

(57) A fuel cell stack comprises a plurality of fuel cells stacked in modular configuration. A plurality of fuel cells is created on a single piece of electrolyte eg. by screen printing electrodes to form a layer. A plurality of layers may be arranged such that cathodes and anodes of respective layers face each other with a space therebetween to permit supply of fuel maintained by spacers 7. A fuel stack array comprises such a stack connected to an adjacent further cell stack and electrically insulated from each other (Figures 4A, 4B), fuel being fed and exhausted from one side of a stack, and a further fuel fed and exhausted from the other side, each of the fuels and exhausts being separated by dividers. The feed gases can be fed centrally and shared between cell stacks. Multiple stack arrangements can be built up in any direction (Figs. 5 - 8) and the stack arrays supported within a water-cooled housing (Fig. 9). Failed modules can be removed and replaced. Any number of modules can be added to meet power and voltage requirements.

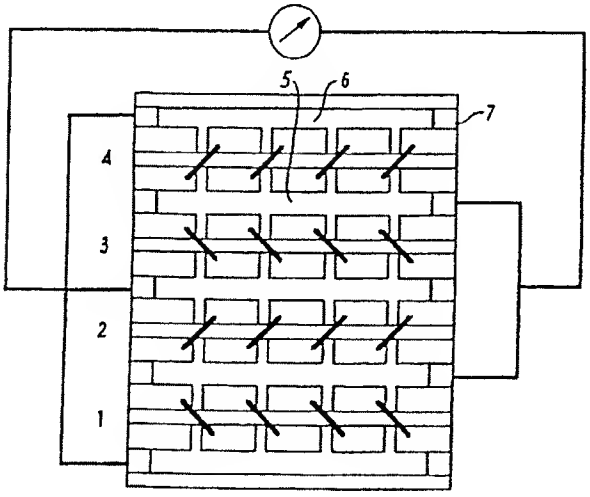

Fig.3

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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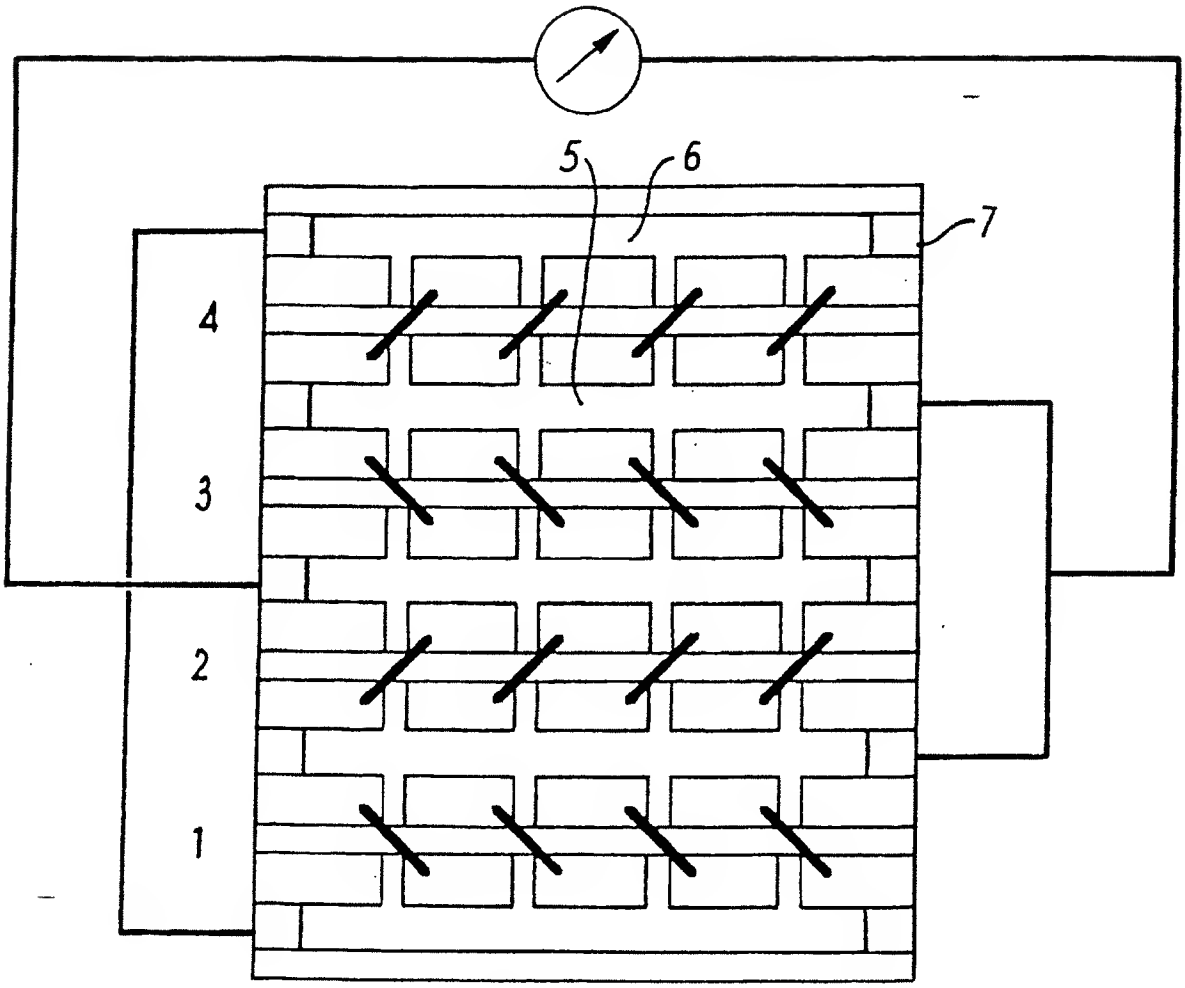


FIG. 3

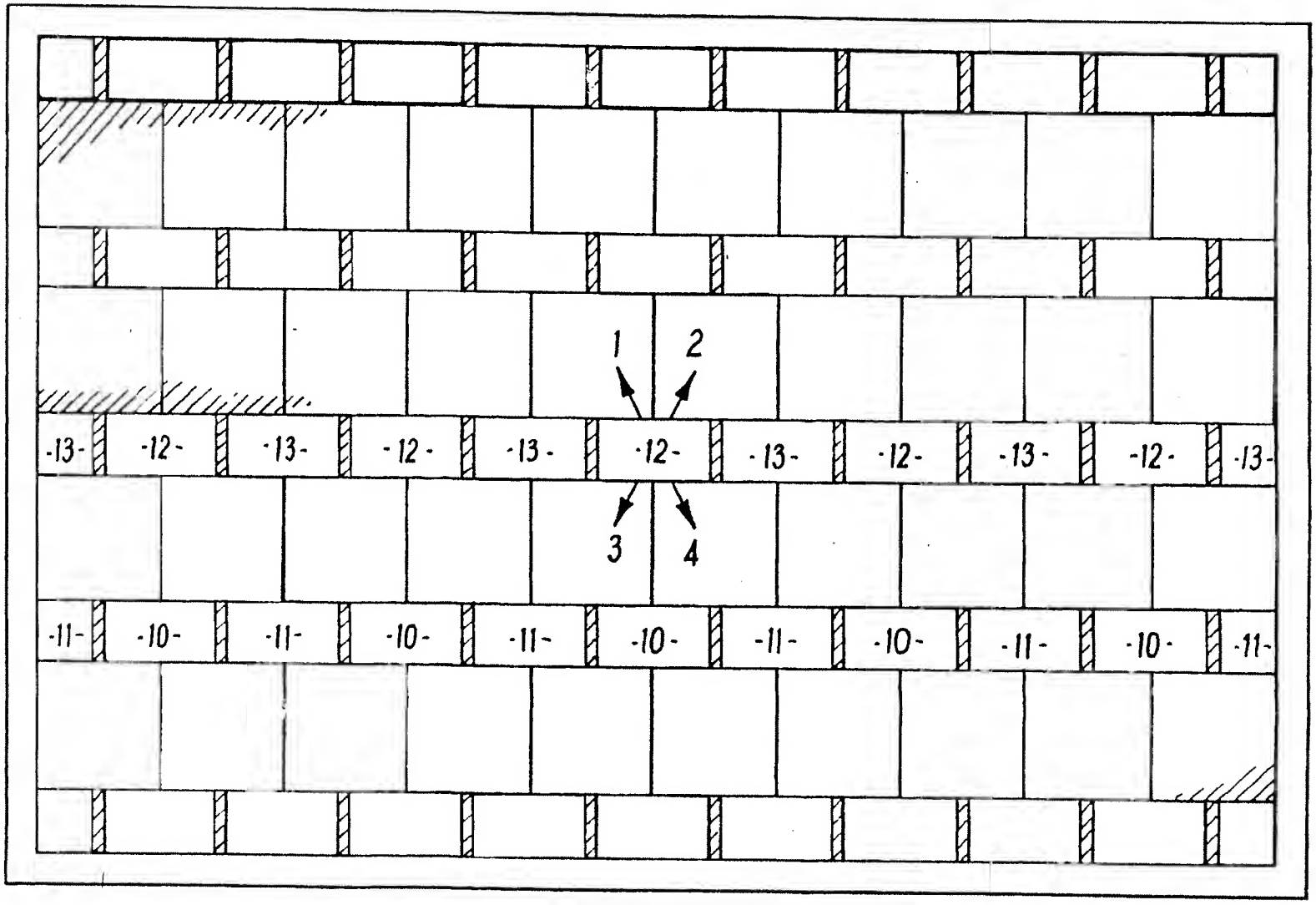


FIG. 5

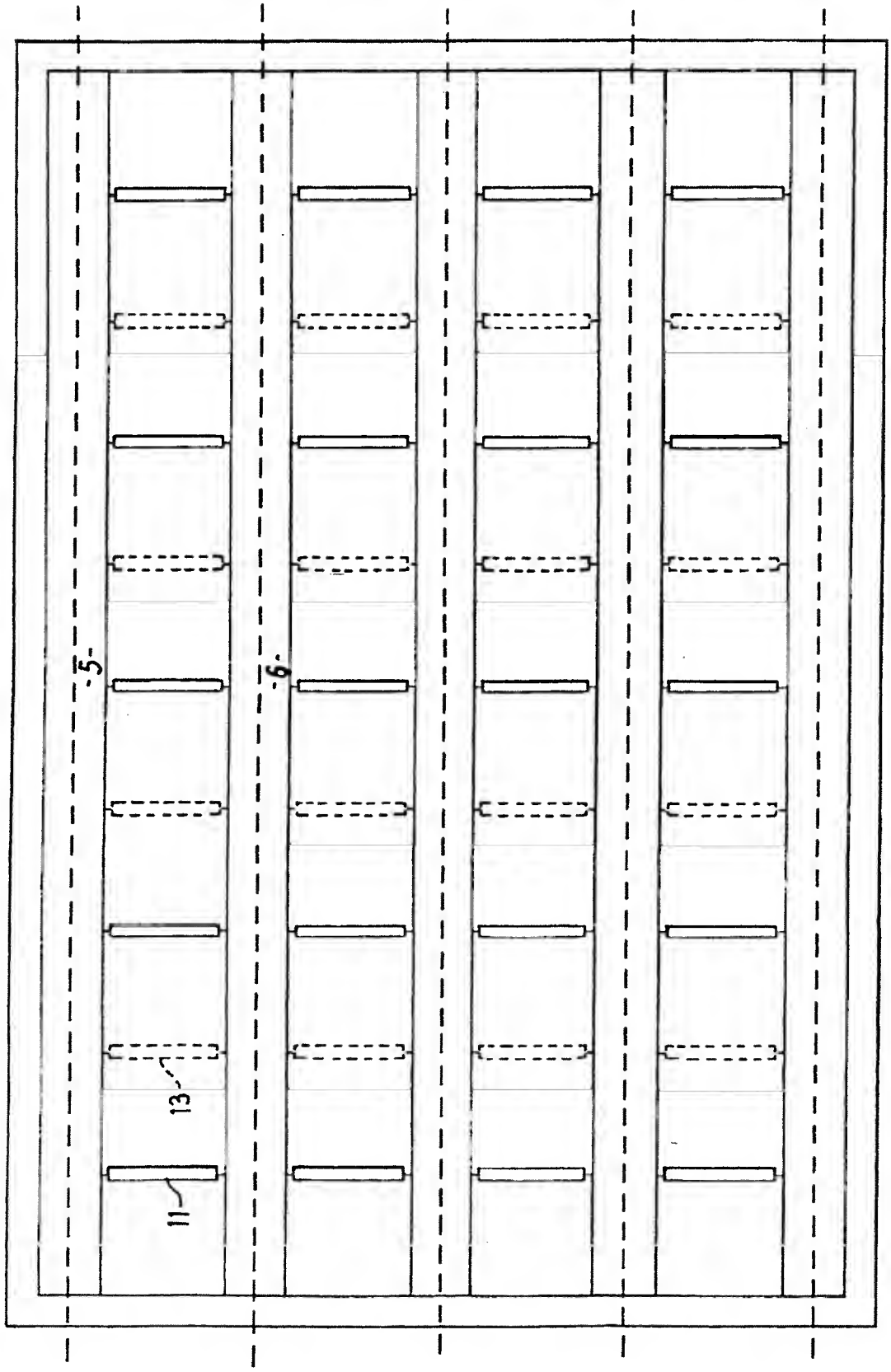
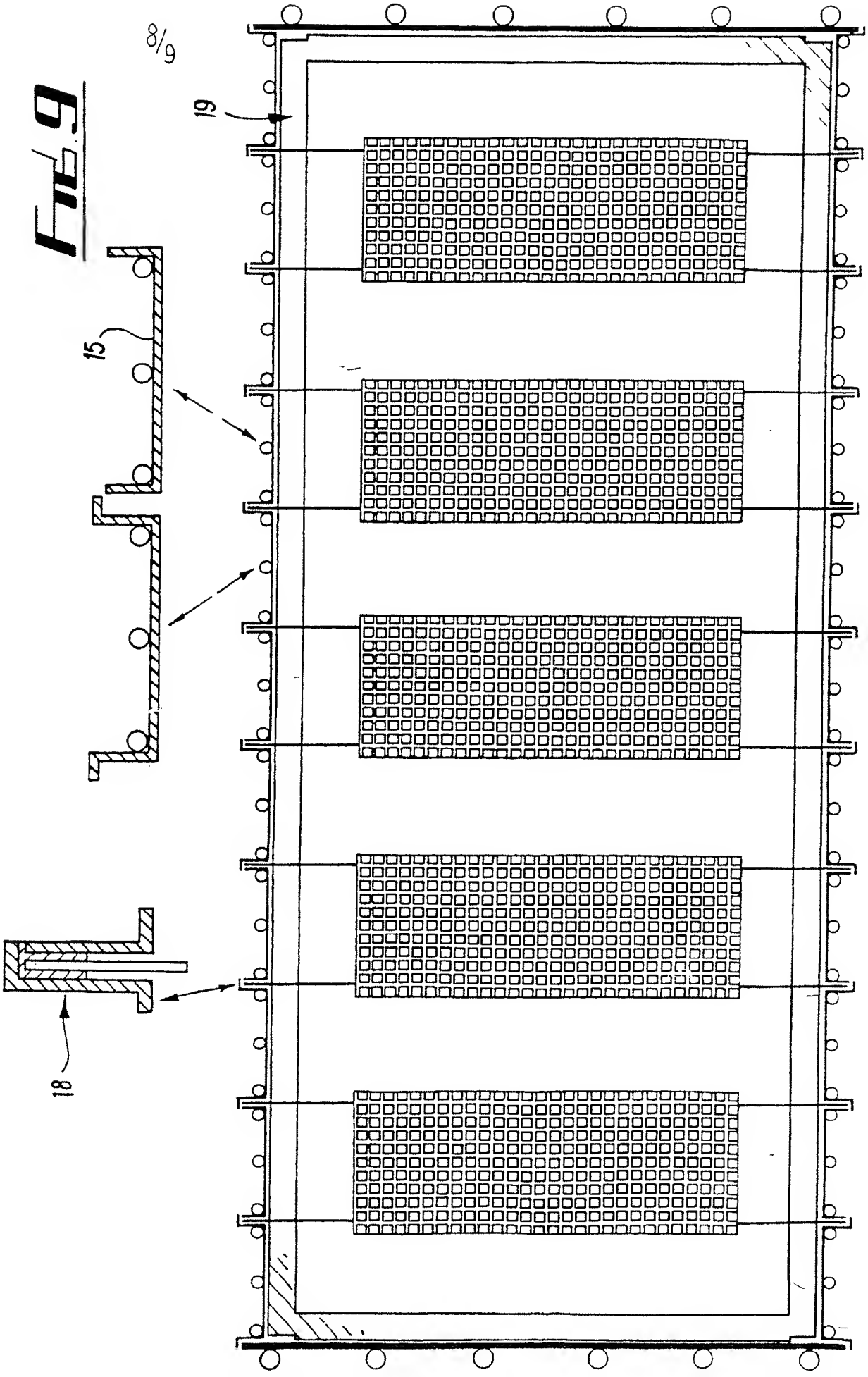


Fig. 7

Fig 9



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"A fuel cell stack and method of stacking fuel cells"

This invention relates to a fuel cell stack and the use of the fuel cells assembled into a stack and housing, for the production of electrical power using a variety of fuel gases and oxidants.

Three main techniques for stack design are as follows:

1) Tubular (as manufactured by Westinghouse);
Advantages are ease of sealing;
Disadvantages are relatively low power density, necessity of support tube, high cost.

2) Monolithic (as manufactured by Argonne National Laboratory);
Advantages are high power density, 'one-piece' manufacture, and moderate costs;
Disadvantages are sealing difficulties, manufacturing without component fracture, restrictions in manufacturing flexibility.

3) Planar (as manufactured by Ceramate; Siemens etc);
Advantages are high power density, easier control of manufacturing stages, and moderate costs;

supply of fuel to and from these electrodes.

Preferably the space is maintained by provision of spacers between the cell layers.

Preferably the spacers allow electrical connection of the electrode pairs so that each layer is effectively in parallel with every other layer.

Preferably the spacers act as contact for connecting a power lead to the stack as a means for taking power from the stack.

Preferably wherein the spacers act as a sealant to retain the fuel and exclude foreign matter.

Preferably wherein the spacers provide means to support the structure.

Preferably the fuel cell stack is adjacently connectable to at least one further fuel cell stack to form a fuel cell stack array and said fuel cell stacks being electrically insulated from each other where they join.

According to a further aspect of the present invention, there is provided a fuel cell stack array comprising at least two adjacently connectable fuel cell stacks electrically insulated from each other wherein a fuel is fed to, and its exhaust products are removed from, one side of a stack; and a further fuel is fed to, and its exhaust products are removed from, the opposite side of said stack, each of said fuels and its exhaust products being separated by dividers.

Preferably the said fuels are provided centrally and

Also according to the invention a fuel cell comprises a planar solid electrolyte; on one side of the electrolyte a planar anode; on the other side of the electrolyte a planar cathode; and means for providing fluid fuels to the faces of anode and the cathode remote from the electrolyte.

Preferably the cathode and the anode are formed of porous material, and the fuels are gaseous fuels. Optionally, the cathode and the anode are formed on the planar solid electrolyte by a screen printing process. Optionally there may be provided a plurality of fuel cells formed on a single planar solid electrolyte, comprising a plurality of planar anodes spaced from each other, and an equal number of spaced planar cathodes. Such a plurality of fuel cells will be referred to herein as a multiple fuel cell.

Further, according to the invention a stack of multiple fuel cells may also be provided by arranging a plurality of multiple fuel cells according to the invention with alternately the anodes and the cathodes in face-to-face spaced arrangement. In such a stack, the spaces between the adjacent anodes and cathodes allow the supply of fuel to these electrodes.

Preferably the spaces are provided by placing at the outer ends of each fuel cell stack and in contact with the outer electrodes of each multiple fuel cell electrically conducting spacers which comprise means (a) to allow the electrical connection of all the anodes and of all the cathodes in each stack, and/or (b) to allow the connection of a power lead by which electrical power can be drawn from the stack, and/or (c) to provide a gaseous fuel sealant, and/or (d) to provide means for mechanically holding the stack

reference to the figures in which:

Fig 1 is a fuel cell as combined in a fuel cell stack in accordance with the present invention;

Fig 2 is an illustration of five cells as shown in Fig 1 linked in series on a common electrolyte substrate;

Fig 3 is an illustration of four sets of cells as shown in Fig 1, linked in series/parallel arrangement;

Fig 4a is a front elevation of two fuel cells stacked in accordance with the present invention, electrically separate and showing hydrogen entrance and exit ports;

Fig 4b is a plan view of two fuel cell stacks in accordance with the present invention showing divides separating gas inlets and outlets;

Fig 5 is a plan view of a modular stack arrangement in accordance with the present invention, made up of four fuel cell arrays;

Fig 6 is a three dimensional view of part of the arrangement of Fig 5 showing gas feed and exhaust detail;

Fig 7 is a plan view of modular stack arrangement in accordance with the present invention;

Fig 8 is a three dimensional view of part of the arrangement of Fig 7;

corresponding cathode 4 screen printed (or otherwise created) on the other. To give 5 cells, 5 such prints or strips are made on the one piece of electrolyte 2, with an electrical break between each strip. When these strips are connected in series by joining the cathode 4 of one cell to the anode 3 of the next, the voltage between the two extreme ends of any one layer will be 5 times the voltage of a single cell. Although only five cells are shown in the Figure 2, screen printing allows numerous cells to be created on one piece of electrolyte to give a high voltage output.

Figure 3 is an extension of Figure 2, and shows four layers of cells (numbered 1 to 4) arranged with cathodes 4 facing each other, and anodes 3 facing each other, with a gap between these electrode pairs to admit and channel the respective gas. The spacer 7 between the electrodes acts as both spacer 7 to form a gap for the gas, and electrical conductor to join top and bottom of the electrode pairs together and to act as a stud contact to take off a power lead. It also acts as a sealant to retain or exclude gases, and 'adhesive' to hold the structure together.

Each of the four layers of the assembly generates 5 volts, but each layer is effectively connected in parallel with every other layer such that four times the current delivered by one, will be delivered at the same five volt (open-circuit) level.

Figure 4a is a further development of Figure 3, but for simplicity, now shown without the electrical connections. Two cell stacks 6 are shown next to each other, but electrically insulated from one other where they join (the vertical dotted line). Further insulating gas sealants 7 have been added, which cause

Figure 7 shows yet another arrangement, allowing the feed gases to be introduced into simplified ducting between the stack arrays. the exhaust gases exit from the individual cells into channels within the arrays, these passing up (the hydrogen waste gases) and down (the oxygen waste gas) into the respective ducting above and below the arrays.

Figure 8 again shows part of the arrangement of Figure 7, but in three dimensions. The respective feed gas is introduced between each 'tower-block' array, with the waste gases appearing at top and bottom respectively of the channel in the 'tower-blocks'.

Figure 9 is based on Figure 8, but now shows the means of supporting the cell stack arrays within a water cooled housing 15, and the technique of separating gas feeds and exhausts. Electrical connections, and gas pipework, into and out of the housing are, for simplicity, not illustrated. The housing is made from only two types of castings, one 'male' 16, and one 'female' 17, probably of nodular cast iron, to give dimensional stability, and to allow for welding. The supports for the cell arrays, could be of alumina or other suitable ceramic, which completely surrounds the stacks, and is sealed to them with ceramic adhesive/cement. Where these supports enter the outriders of the water cooled castings, sealing with silicone rubber or other elastomer 18 should become possible, as the temperature should not be above 150 celsius. This will give some compliance to accommodate thermal expansion differences between the cooled housing, and the stack support components. Insulation baord 19 is provided.

The modularity approach allows arrays to be built

4) A unique approach of back-to-back cell design with integral gas routing, simplifies fuel and oxidant management, enhances gas reaction rates, and reduces weight and material usage.

5) The manufacturing stages and gas sealing, are straightforward, and are based on well established technology. Most layering and interconnecting operations should be possible by the (inexpensive) screen printing route.

6) All internal electrical connections can be in the fuel gas manifold, allowing the use of metallic connectors at the typical 1000C working temperature.

7) The stack has high built-in manufacturability, maintainability, and serviceability.

cathodes face each other and anodes face each other to form electrode pairs, and such that there is space between adjacent anodes and adjacent cathodes to permit the supply of fuel to and from these electrodes.

8. A fuel cell stack as claimed in Claim 7 wherein the space is maintained by provision of spacers between the cell layers.

9. A fuel cell stack as claimed in Claim 8 wherein the spacers allow electrical connection of the electrode pairs so that each layer is effectively in parallel with every other layer.

10. A fuel cell stack as claimed in Claim 8 or 9 wherein the spacers act as contact for connecting a power lead to the stack as a means for taking power from the stack.

11. A fuel cell stack as claimed in Claim 8, 9 or 10 wherein the spacers act as a sealant to retain the fuel and exclude foreign matter.

12. A full cell stack as claimed in Claim 8, 9, 10 or 11 wherein the spacers provide means to support the structure.

13. A fuel cell stack as claimed in Claim 7, 8, 9, 10 or 11 which is adjacently connectable to at least one further fuel cell stack to form a fuel cell stack array; said fuel cell stacks being electrically insulated from each other where they join.

14. A fuel cell stack array comprising at least two

comprising a plurality of arrays of fuel cell stacks modularly arranged are reversibly conjoined by means of extension pieces.

21. A method of stacking fuel cells as claimed in Claim 20 wherein extension pieces are provided, said extension piece having means for passage of fuel and electricity between the cell stacks which they conjoin.

22. A method of stacking fuel cells as claimed in Claim 20 or 21 wherein each module and extension piece may be individually removed and replaced.

23. A fuel cell stack and method of stacking fuel cells substantially as hereinbefore described with reference to the accompanying drawings.